PFC Group Work Summary

PMI Laboratory Experiments 2005 November

- PISCES group – UCSD
    - Be_2C formation
    - Chemical erosion mitigation by Be
    - Be-W alloy growth

- PMI group – UIUC
    - FLiRE: He pumping by liquid Li
    - ESP-Gun: initial operation
    - IIAX: temperature enhanced sputtering

- SNL/CA and INL groups
    - He trapping in liquid Ga
    - Be-W reactivity
    - Recommissioning TPE at INL

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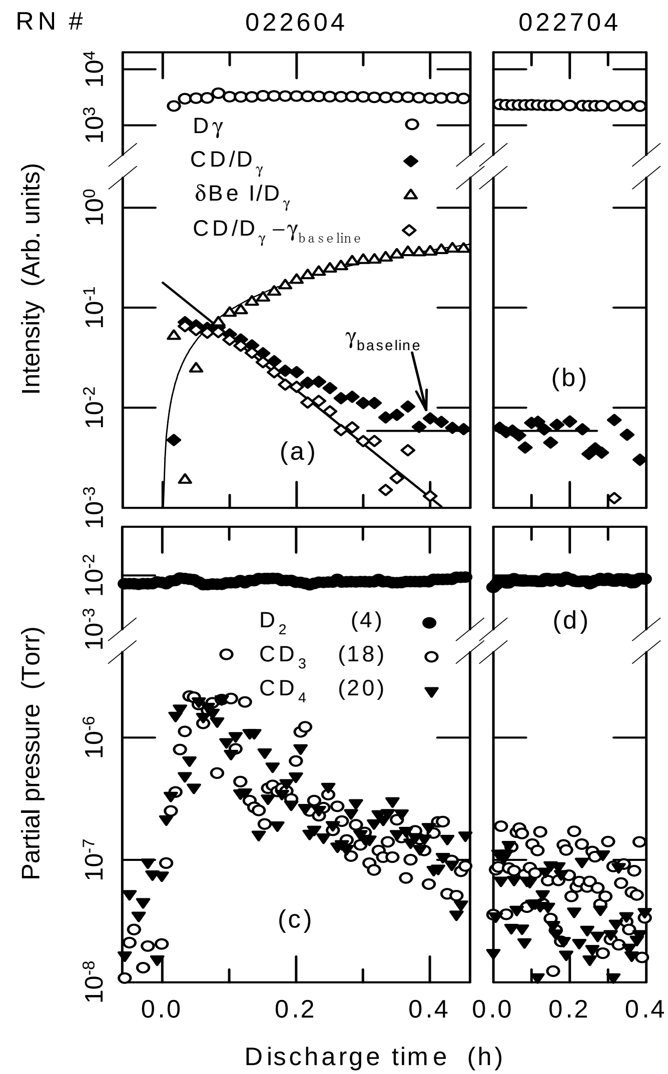
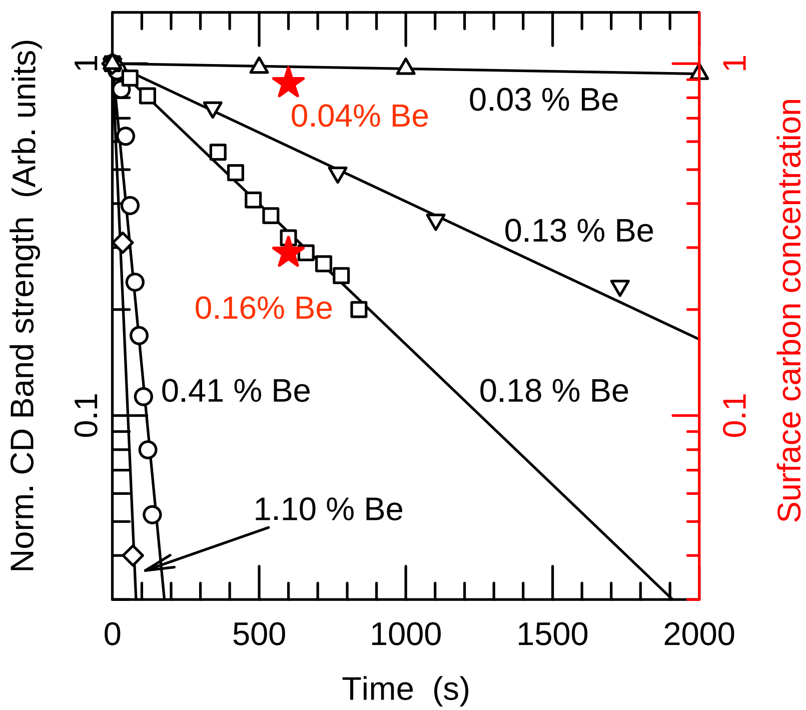
Be_2C layer formation time is measured by decrease in CD band intensity

- CD band intensity near C target drops w/ time as Be erosion signal from target increases
- CD signal approaches background device level (walls)
- RGA signals during plasma exposure shows similar drop in m/q = 20 & 18 (CD_4 & CD_3)
- Identical exposure of Be coated sample on the following day show changes persist and are not associated with plasma start-up or wall changes



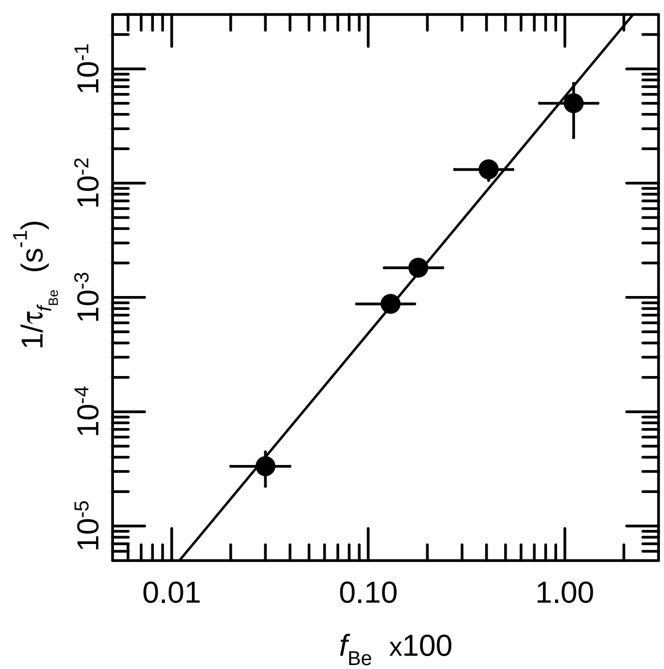
Chemical erosion mitigation time depends on Be plasma concentration

PISCES-B conditions: Γ_{pl} = 3e18 $cm^{-2}s^{-1}$, 400°C



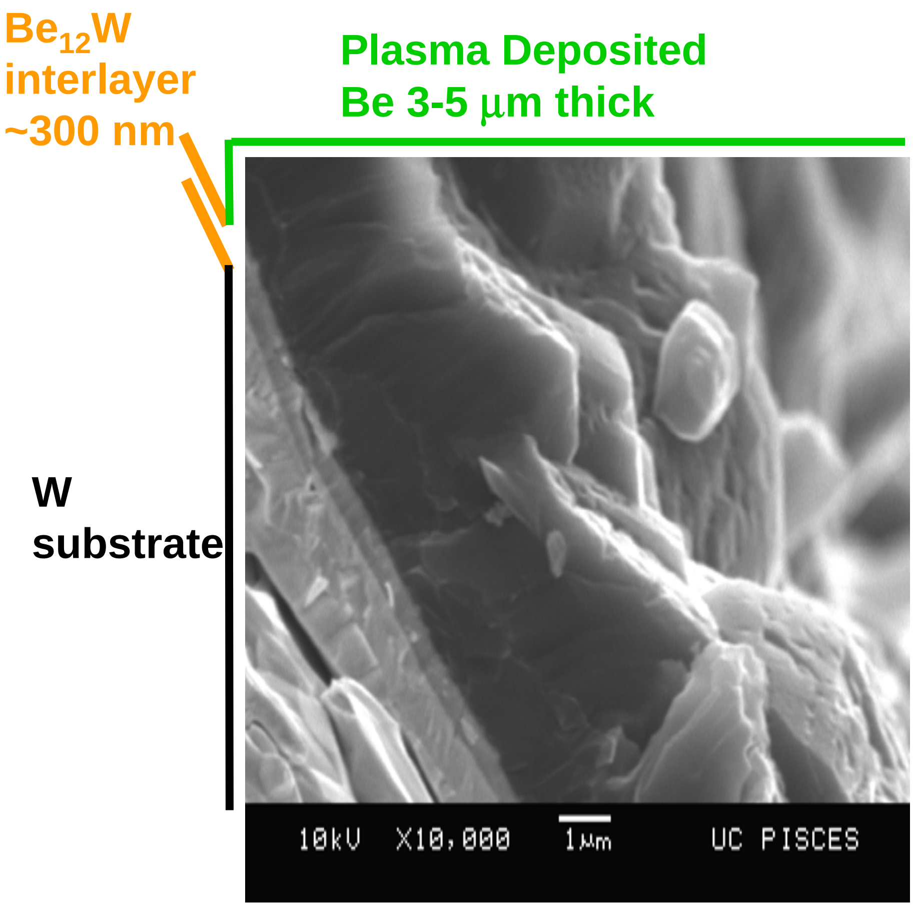
Increasing Be concentration decreases the layer formation time, solid lines are exponential decay fits: $I_{CD} = \exp(-t/\tau_{f_{Be}})$

We obtain the scaling of the erosion decay rate by fitting data with a power law expression: $1/\tau_{f_{Be}} = \alpha f_{Be}^{\beta}$, obtaining α = 785 s^{-1}, β = 2.07



Similar scaling measurements with surface temperature, ion flux, energy are underway.

Sputtering from energetic plasma ions can inhibit Be-W alloy growth, but growth kinetics are unaltered if Be surface layers form



f_{Be}=0.005, t_{exp}=3600 s, 800°C

- Sectioned targets exposed at 800°C reveal $Be_{12}W$. $Be_{12}W$ growth kinetics are consistent with IPP data
- $Be_{12}W$ layer growth is diffusion limited. $D_{800°C}$~1.7×10^{-13} cm^2s^{-1}.
- The $Be_{12}W$ phase seems thermo-dynamically more stable than Be_2W or $Be_{22}W$
- Beryllide formation observed at temperature as low as 570°C during plasma bombardment
- Energetic ion bombardment can remove Be surface layer, limiting $Be_{12}W$ interlayer growth
- Temperature variation studies & layer growth modeling are currently underway

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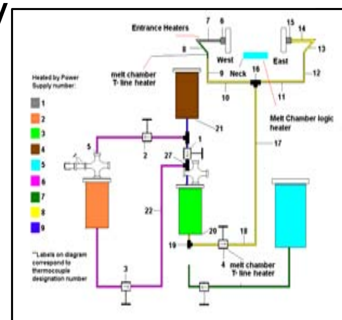
Flowing Lithium Retention Experiment (FLiRE)

- FLiRE has been redesigned with greatly increased reliability
  - Shorter flow path
  - Viewports added to watch flow into bottom chamber
- A shutter has been added to prevent ions from bombarding the flow ramp
- Qualitative measurements have shown liquid Li does pump He ions
  - Measurements show that ions implanted into the ramp prior to flow are seen in the bottom chamber, but not to the same degree as ions implanted directly into the flowing Li
- Measurements are underway to determine the ion flux on the flowing Li and determine a quantitative retention coefficient (R)

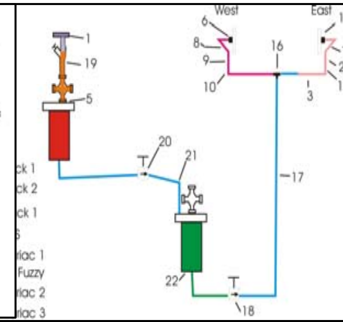
He pressure in Torr vs. time

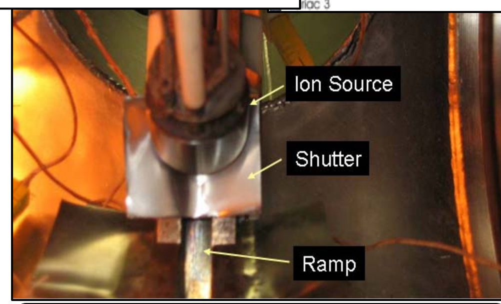
(scales identical & linear from 1e-9 to 5.1e-8 Torr on the y-axis and range of 200 seconds on the x-axis)

Original Li flow path



Current Li flow path

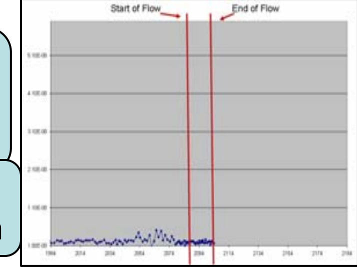




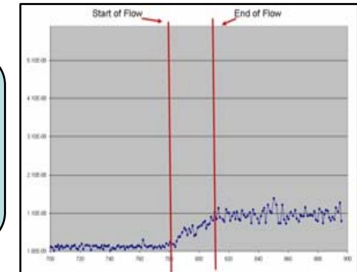
Ion source and shutter placement inside chamber

Ion source operating in test chamber

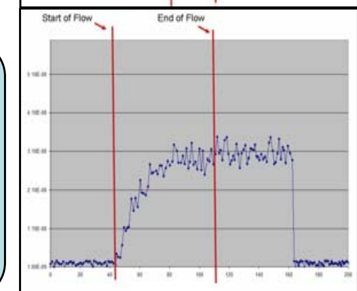
Static He Run



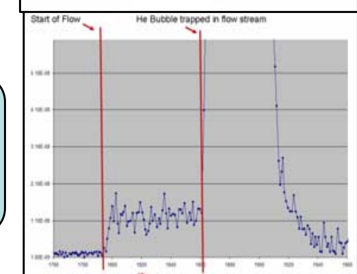
Shutter closed throughout flow



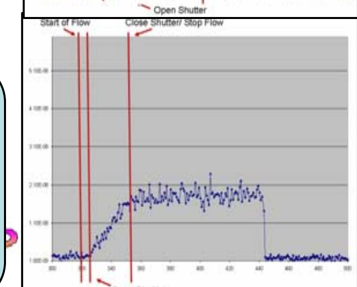
Ion source on ramp before and during flow Estimated R = 2.7%



Ion source on ramp until start of flow

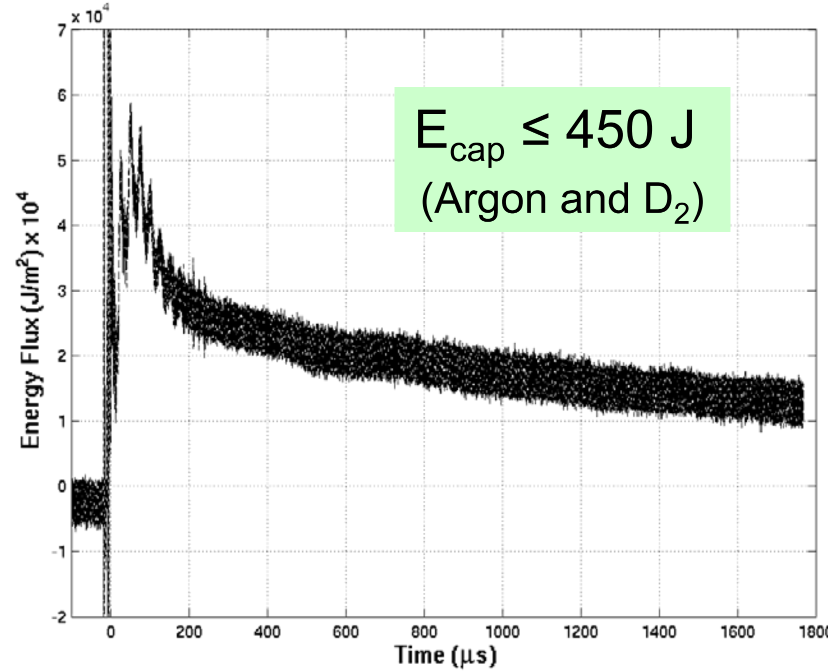


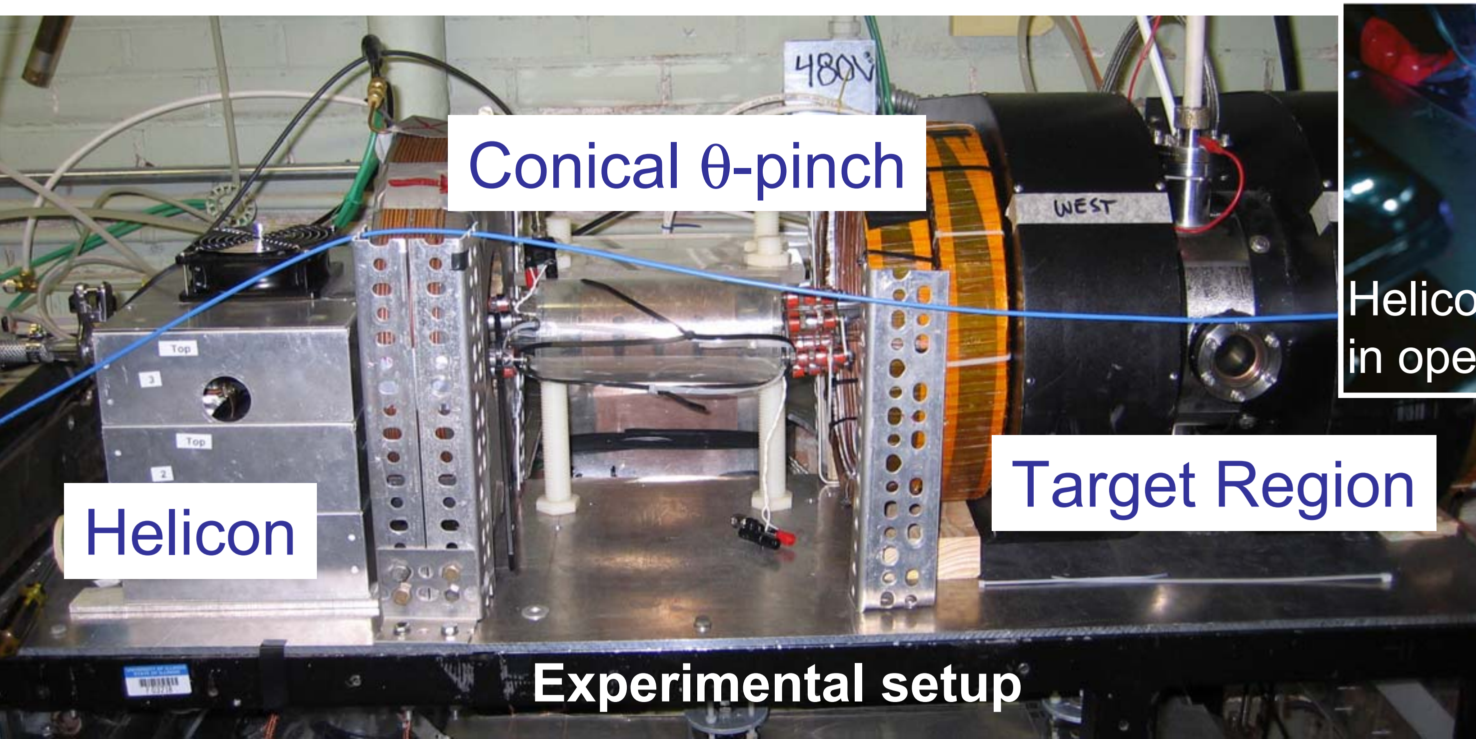
Open and close shutter during flow Estimated R = 1.4%

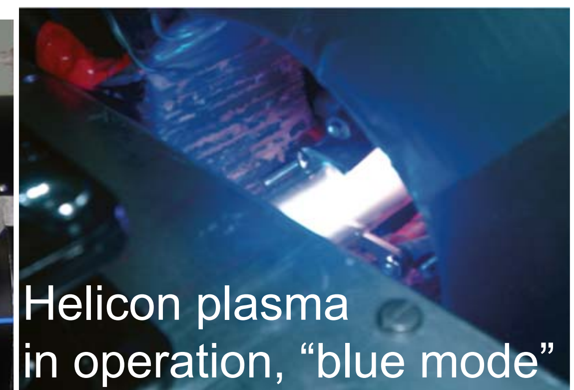


ELM Simulating Plasma Gun (ESP-gun)

ΔT of Cu target (monitored by IR Photoresistor)
- Up to 20ºC Temperature rise.
- Results in 90 kJ/m² on target.







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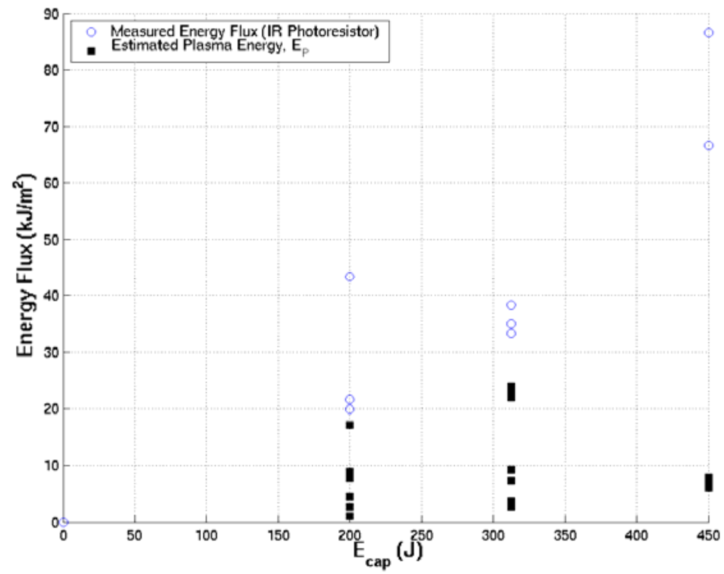
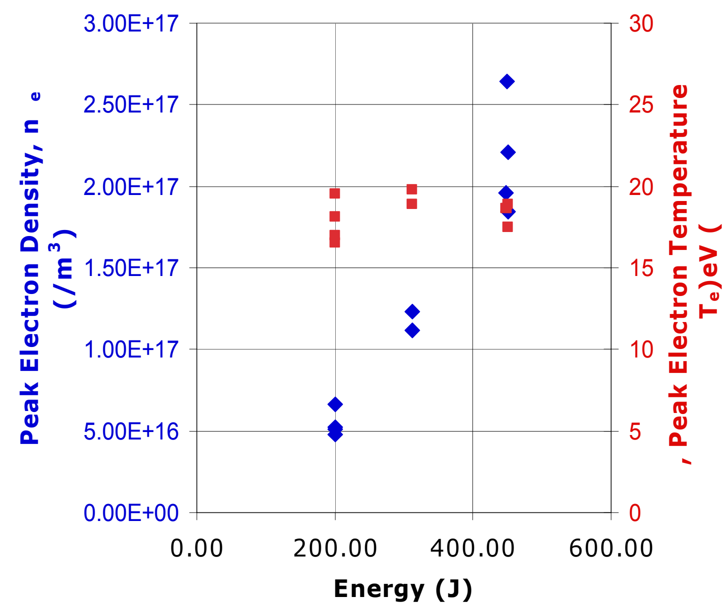
ESP-gun (2)

$E_{cap} \leq 450$ J
(Argon and D_2)

- Triple Langmuir Probe measurements (Argon)
  - $6(10)^{16} \leq n_e \leq 3(10)^{17}$ /m^3
  - $30 \leq T_e \leq 120$ eV
- Thermal measurements on the order of estimated $E_{plasma} \sim 3/2\, n_e k T_e$



- Preliminary D_2 Operation
  - $5(10)^{16} \leq n_e \leq 2(10)^{17}$ /m^3 (Scales linearly wrt E_{cap})
  - $T_e \sim 20$ eV (constant wrt E_{cap})



Based on IR Photoresistor measurements of energy flux on target, energy flux in ESP-gun is expected to scale to 3.8 MJ/m^2 for an input energy of E_{cap} = 21 kJ (12 μF cap bank @ 60 kV)

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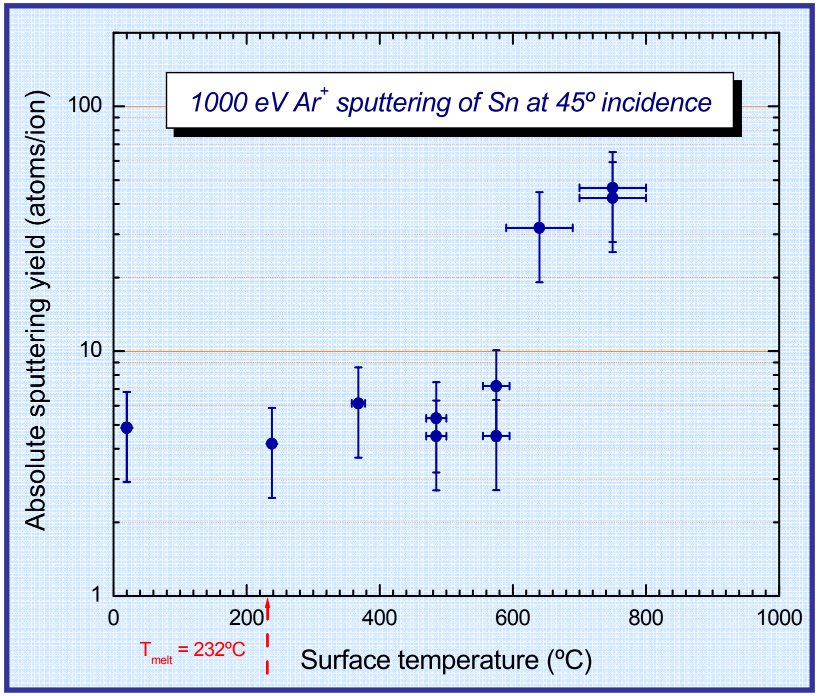
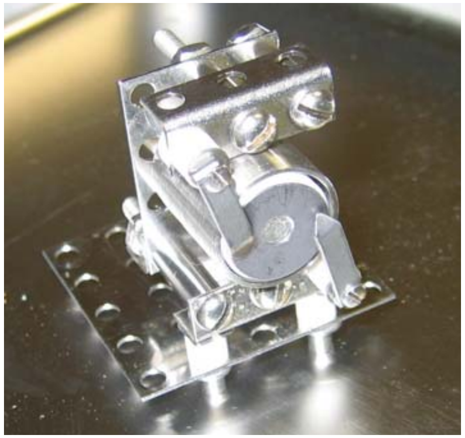
Ion-surface InterAction eXperiment (IIAX)

- Recent progress in measuring temperature-enhanced sputtering (TES) in liquid Sn – TES noted in Ar^+ sputtering of liquid Sn around 600º (previously, due to hardware limitations, measurements were limited to < 400ºC)
- Wrapping up liquid Sn work – isolating temperature where the TES takes effect for various ion species and energies to pin down a trend for model development





IIAX Future Work Plans

- Switching to nearer-term (ITER, FIRE) materials – All metal machines (Be & W)
- In particular, the erosion properties of W coatings on Be samples at temperatures ranging from 20 – 1200ºC (near Be's melting point but well shy of $Be_{12}W$'s of ~1500ºC)

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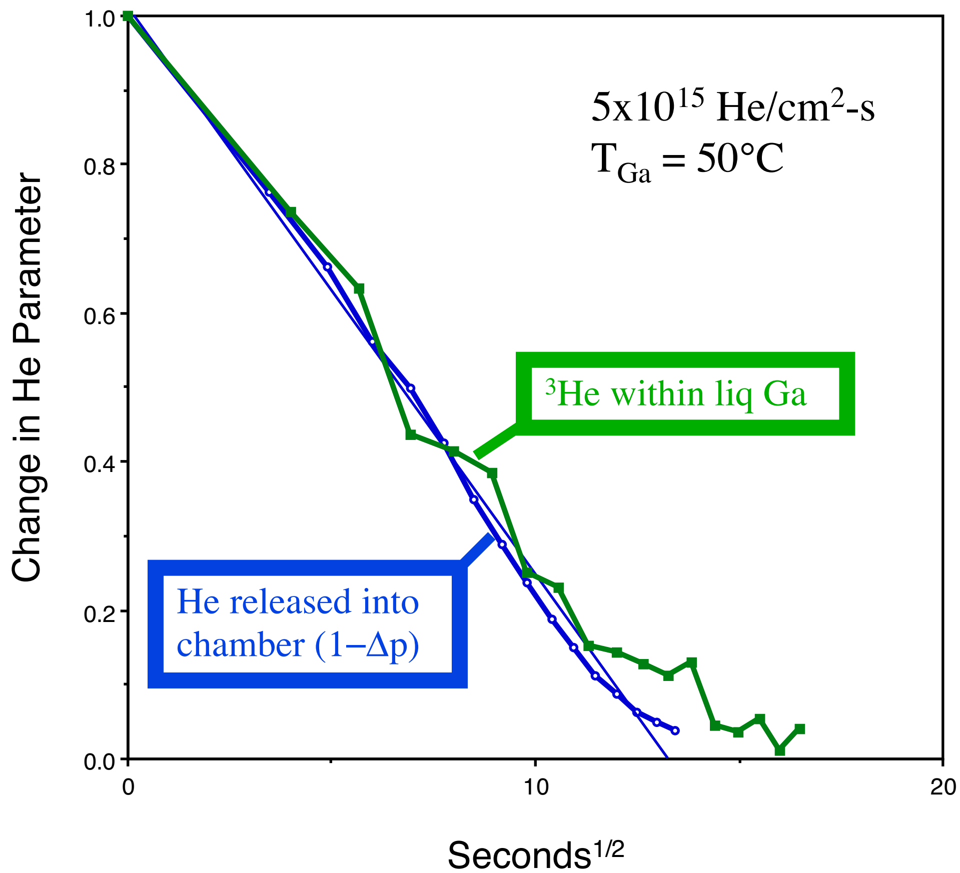
Two different experiments find He re-emission from liquid Ga consistent with 4000 atom bubbles.

- Experiments expose static liq. Ga film to steady-state He Penning plasma.

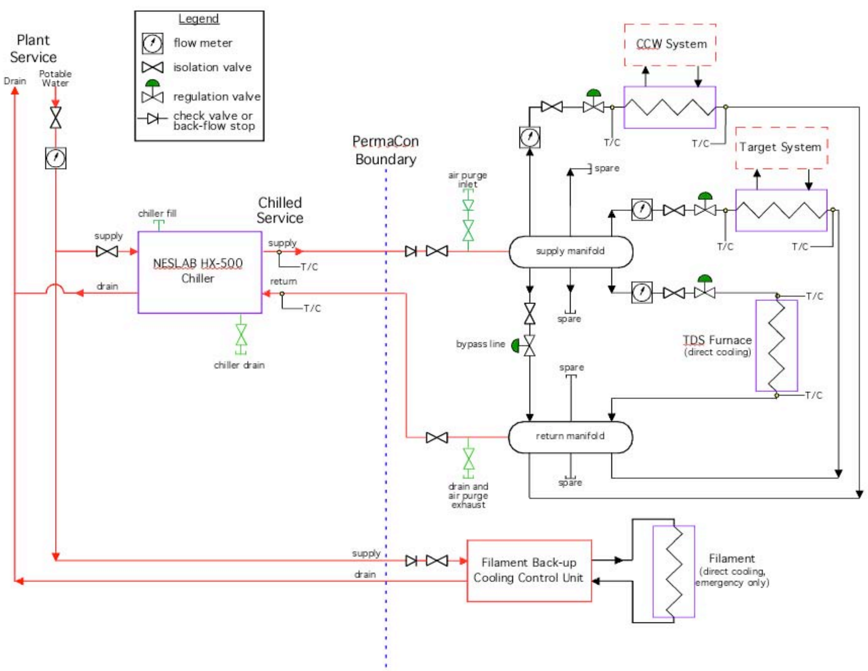


- Observed on plasma extinction:
  - ^{3}He within liq Ga dropped as $t^{1/2}$ (measured by $^3He(d,p)^4He$ NRA)
  - He emitted from liq Ga as $t^{1/2}$ (Δp increase in small chamber)
- Draining of He from .25mm film has approx. $t^{1/2}$ time dependence: $M(t)/M(0) \approx (4Dt/\pi L^2)^{1/2}$
- Fit gives $D \approx 0.1\ D_{He}$ in Ga, or $dia_{bubble} \approx 10\ dia_{Ga} \approx 2.7$ nm

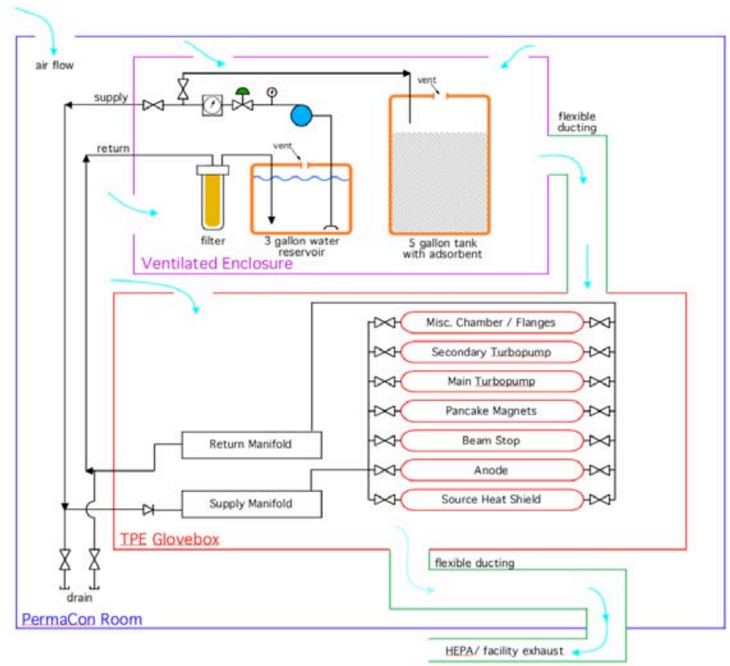
→ ~ 4000 He/bubble

Progress on TPE:

- UBED installation complete; gas-handling system leak testing is underway and will be followed by UBED hydride and recovery cycle testing
- Upgrades and repairs to Component Cooling Water System are complete; leak testing, system purge and cleaning are underway; as consequence of purge, ~ 50 liters of tritiated (2 mCi/l) waste water must be disposed; remaining task is integration of system with the closed-loop chilled water supply
- Emergency source cooling system modifications and testing are underway; system activation testing will be performed as part of integrated cooling system tests



Layout of integrated cooling system for TPE
Tritiated cooling water is isolated from plant coolant service by 2 separate intermediate systems.



CCW purge and clean system is design to handle mildly tritiated waste water.

Progress on TPE, cont.:

- Vacuum system leak testing underway with He pressurization (looking for sizeable leaks prior to source and target refurbishment)
- Vacuum system purge and baking has released ~5 Ci from surfaces; with the threat of T uptake reduced, the next step is source removal, evaluation, and refurbishment; also refurbishment of target assembly
- New 35 kW power supply with multi-mode control (V, I, or power) is installed
- Safety review and operations documentation preparation is underway; INL internal safety review to be completed in December
- A *required* upgrade of the PermaCon room ventilation blower is being procured.
- Tritium shipment to STAR planned for December or January; 500 Ci source will be available for TPE in February
- A non-tritiated plasma discharge system has been assembled (from donor experiments, often without *exact* permission...) to test functionality of TPE diagnostics without difficulty prior to installation on TPE (e.g. fine-tuning operation of the reciprocating probe, development of a probe array, and eventual testing of a spectrometry system)